OLIVER HEAVISIDE AND HIS INFLUENCE ON MODERN RADIO RESEARCH

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Although the term "Heaviside layer" has now passed into common use, it is probable that only a small fraction of its users have a precise knowledge of its origin and meaning. It is, nevertheless, likely to be the most permanent memorial of an Englishman who, through his brilliant theoretical studies of electricity, has exercised a profound influence on the technique of radio communication.

OLIVER HEAVISIDE

Oliver Heaviside, the centenary of whose birth has recently been celebrated, began his career as an employee of a commercial telegraph company, but while still a young man deafness forced him to retire. He subsequently devoted the remainder of his lifetime (he died in 1925) to mathematical studies of electricity. Although he was primarily an applied mathematician his interests were wide, ranging from theoretical contributions on vector analysis and operational calculus to the investigation of the practical problems of telegraphy and the study of electrostatic and electromagnetic induction.

The work by which he is best known is, in a sense, an offshoot of his examination of the properties of concentric electrical conductors. He visualised an immense concentric system comprising the earth as one conductor surrounded by a conducting shell in the upper atmospheric regions. Heaviside reasoned that if such a layer existed in the upper atmosphere, then electromagnetic radiation, or in present-day terms, radio waves, should be prevented from leaving the earth by being absorbed or reflected. This supposition gained steady support as the nature of the propagation of radio waves became better known, but it was not until after Heaviside's death that Professor E. V. Appleton, in London, demonstrated the presence and properties of a reflecting layer above the earth.

Appleton transmitted short pulses of radio waves almost vertically upwards and was able to detect echoes as the pulses were reflected and received back on the earth. The first investigations showed the presence of a reflecting layer about 40 miles above the earth, well above the ceiling of any aircraft and even of meteorological balloons. This was named the Heaviside layer. Further work indicated the existence of a second layer about 150 miles above the earth, and this has now been called the Appleton layer.

An interesting development of the technique of transmitting short trains of waves arose from the discovery that these pulses were capable of being reflected by solid objects such as ships at sea and aircraft in flight. The investigation of this phenomenon by a research team headed by Watson-Watt led to the development of radar as a military and navigational device.

Since the pioneer work of Appleton, there has been intensive study of the phenomena of reflection. It is a subject of particular interest to the commercial international radio-communications companies and broadcasting organisations, which attempt, in their respective spheres, to ensure regular reception of their transmissions by day and night in all parts of the world.

The reflecting regions of the upper atmosphere are now known collectively as the ionosphere, a term derived from the fact that these regions are zones where the atmosphere is rendered conductive by a process known as ionization, induced by ultraviolet radiation from the sun. The extent of ionization varies greatly according to the time of day, season, and latitude, and markedly affects long-distance radio communication. There are now known to be at least three apparent layers, and the Heaviside and Appleton layers are often termed the E and F_1 and F_2 regions, respectively. In the daytime the E region tends to absorb radio waves and normally only reflects signals of comparatively long wave length, about 300 to 30,000 metres. Signals of medium wave length, about 100 to 300 metres, are largely absorbed, but signals of short wave lengths of 10 to 100 metres penetrate the E region and are reflected by the F regions, returning to earth hundreds of miles away and thereby providing long-distance daylight communication.

At night the absorption of the E region is much less and signals of medium wave length can penetrate it and be reflected by the F region. Signals of very short wave length, that is, less than ten metres, normally penetrate both regions without reflection although occasionally, when the ionization in the regions is particularly intense, reflection may occur and give freak results. An example of this is the reception of the London television transmissions on a wave length of seven metres by observers in the Union of South Africa.

This penetration of both regions by signals of very short wave length makes possible the reception of signals from extraterrestrial sources. In the past ten years, receivers of high sensitivity with highly directional aerials have been used to explore the regions outside the earth. The sun is a powerful radiator and the intensity of signals from it has been associated with the appearance of sunspots and of magnetic storms on the earth. It has also been discovered that intense radiation appears to originate in other parts of the universe, notably in the neighbourhood of certain nebulae. This work is of exceptional interest to astronomers as it places in their hands a new instrument with which to study the universe. Not only is it now possible to examine regions outside the earth with something other than a telescope; it is even possible to send a beam of radio waves into space and receive back reflections from such a comparatively near object as the moon.

This newest branch of science, radio-astronomy, is already being actively studied, and there are important schools of research now operating in England and Australia. Although this latest development is far removed from the original speculations of Oliver Heaviside, it has been reached by the logical development of his ideas and it will no doubt in its turn yield as striking new advances.

Ed. Note: Oliver Heaviside's three-volume work, *Electromagnetic Theory*, has recently been republished by Dover Publications, Inc., New York City, in a one-volume edition priced at $7.50.